

(19)

Europäisches Patentamt  
European Patent Office  
Office européen des brevets



(11)

**EP 0 241 522 B1**

(12)

**EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention  
of the grant of the patent:

26.02.1997 Bulletin 1997/09

(51) Int Cl.<sup>6</sup>: **G01N 21/35, G01N 21/61**

(86) International application number:  
**PCT/US86/02150**

(21) Application number: **86906219.0**

(22) Date of filing: **10.10.1986**

(87) International publication number:  
**WO 87/02460 (23.04.1987 Gazette 1987/09)**

**(54) DIGITAL ANESTHETIC AGENT ANALYZER****DIGITALE ANALYSEVORRICHTUNG FÜR ANÄSTHETISCHE MITTEL****ANALYSEUR NUMERIQUE D'AGENT ANESTHESIQUE**

(84) Designated Contracting States:  
**AT BE CH DE FR GB IT LI LU NL SE**

(30) Priority: **11.10.1985 US 786736**

(43) Date of publication of application:  
**21.10.1987 Bulletin 1987/43**

(73) Proprietor: **Andros Incorporated**  
**Berkeley California 94710 (US)**

(72) Inventors:

- **PARNOFF, George, Kenneth**  
**Walnut Creek, CA 94598 (US)**
- **PASSARO, Robert, Eugene**  
**Richmond, CA 94804 (US)**
- **ROGERS, Raymond, Earl**  
**Oakland, CA 94601 (US)**

- **WILLIAMS, Kevin, Graham**  
**Pinole, CA 94564 (US)**

(74) Representative: **Bayliss, Geoffrey Cyril et al**  
**BOULT, WADE & TENNANT**  
**27 Funnival Street**  
**London EC4A 1PQ (GB)**

(56) References cited:

|                        |                        |
|------------------------|------------------------|
| <b>WO-A-85/00655</b>   | <b>US-A- 3 120 608</b> |
| <b>US-A- 3 790 798</b> | <b>US-A- 3 893 770</b> |
| <b>US-A- 3 898 462</b> | <b>US-A- 3 932 040</b> |
| <b>US-A- 3 953 734</b> | <b>US-A- 4 011 859</b> |
| <b>US-A- 4 013 260</b> | <b>US-A- 4 110 619</b> |
| <b>US-A- 4 153 837</b> | <b>US-A- 4 204 768</b> |
| <b>US-A- 4 281 248</b> | <b>US-A- 4 346 296</b> |
| <b>US-A- 4 423 739</b> | <b>US-A- 4 480 190</b> |
| <b>US-A- 4 549 080</b> | <b>US-A- 4 560 873</b> |

Note: Within nine months from the publication of the mention of the grant of the European patent, any person may give notice to the European Patent Office of opposition to the European patent granted. Notice of opposition shall be filed in a written reasoned statement. It shall not be deemed to have been filed until the opposition fee has been paid. (Art. 99(1) European Patent Convention).

**EP 0 241 522 B1**

## Description

This invention relates to infrared gas analyzers and, more particularly, to an improved infrared gas analyzer capable of high accuracy and fast response in connection with difficult to measure gases, yet still relatively low in cost.

Many types of infrared gas analyzers utilize an infrared source to produce and direct infrared energy through an unknown gas mixture contained in a sample cell. The energy passing through the sample cell is detected and electrical signals are produced representative thereof. These signals are processed to produce an output indicating the concentration of one or more of the constituents of the gas in the sample cell.

Such gas analyzers utilize the principle that various gases exhibit a substantial absorption characteristic at specific wavelengths in the infrared radiation spectrum. A gas analyzer of this type is shown and described in U.S. Patent No. 4,013,260, McClatchie et al., issued March 22, 1977, and assigned to the assignee of the present invention. Another type of infrared gas analyzer is shown and described in U.S. Patent No. 3,953,734, Dimeff, issued April 27, 1976, and assigned to the United States of America.

WO-A-85/00655 describes a method and apparatus for determining the level of ethanol in a breath sample. The analyzer detects acetone and water levels using a third wavelength of infrared energy in addition to a first reference wavelength and a second ethanol wavelength. The ethanol read-out is adjusted for the presence of acetone and water. Three filters are used, one for reference, one for ethanol and one for acetone and water vapor.

In each of the above cited patents, and in similar types of infrared gas analyzers, the wavelength band of the beam of infrared energy passing through the sample cell containing the unknown gas mixture is changed periodically by the interposition on one or more filters in the path of the light beam. Typically, each filter passes only radiation at a narrow band corresponding to a characteristic absorption wavelength band of a particular gas of interest. Another filter may also be used as a reference filter at a wavelength band close to but not substantially overlapping the characteristic absorption wavelength band of any of the gases present in the sample cell.

Gas analyzers of the foregoing described type usually continuously reference the radiation detected at the characteristic bands to radiation detected at reference levels (i.e., a non-absorbed wavelength and a dark or totally blocked level). By doing so, the effect of so-called drift is minimized, and the effect of background noise is reduced. Drift can occur as a result of contamination on the windows in the sample cell which will attenuate the radiation passing therethrough and which could be interpreted erroneously as indicating the presence of the gas to be detected in the gas sample. Drift can also be

caused by shifts in the output of the detector, inherent in many detector constructions, and temperature changes in the source of the infrared radiation.

Gas analyzers of the foregoing described type, in spite of their high accuracies, still can experience error introduced by a variety of factors. One of such factors is variation in the temperature between different components of the gas analyzer. Temperature, of course, can often be stabilized through expedients such as heat sinks, coolers, etc. However, the use of such elements introduces significant cost increases which may be undesirable.

Another error factor is the presence of certain gases or combinations of gases in the sample cell having absorption bands which substantially overlap. For example, the absorption band of water vapor is very wide and may overlap the absorption band of other gases present in the sample cell. Without correcting for this, significant error can result. The very strong absorption characteristic of carbon dioxide may also cause errors in the observed measurements for other gases present where there is even a small overlap.

The effect of some temperature variations on accuracy can often be reduced by positioning the rotating filter wheel at the input side of the sample cell (i.e., between the infrared source and the sample cell) rather than at the outlet side (between the sample cell and the detector). Although certain other problems may be introduced by such positioning of the filter wheel, such positioning is preferred and the additional errors introduced by such positioning are often tolerable.

Nevertheless, for certain gases or gas mixtures, higher accuracy is needed than has been typically achieved in prior art devices without extraordinary expense. For example, in the measurement and monitoring of gases being administered to an anesthetized patient undergoing surgery, the patient's inhaled and exhaled gas mixture may include percentages of gases such as halothane, methoxyflurane, isoflurane and enflurane, as well as carbon dioxide and water vapor. The absorption characteristics of these various gases differ widely. For example, the absorption of carbon dioxide at its characteristic wavelength may be many times greater than the absorption of halothane at its characteristic absorption wavelength. Where the sample cell must be small, for fast response times in the analyzer, error correction becomes even more significant.

Accordingly, there remains a need, particularly in connection with the monitoring of anesthetic agents and associated gases, to provide a gas analyzer having a fast response time along with a high accuracy and stability at a reasonable price.

It is an object of the present invention to provide an improved gas analyzer.

Another object of the invention is to provide a gas analyzer of high accuracy and stability which is relatively low in cost.

Another object of the invention is to provide a gas

analyzer which is particularly well-suited to use in connection with the measurement of gases in inspired and expired gases of a patient under anesthesia.

Other objects of the invention will become apparent to those skilled in the art from the following description, taken in connection with the accompanying drawings wherein:

FIGURE 1 is a block diagram of an infrared, non-dispersive gas analyzer incorporating the invention; FIGURE 2 is a plan view of the filter wheel utilized in the gas analyzer of FIG. 1;

FIGURE 3 is a graph illustrating the absorption characteristics of various gases which may be monitored with the invention;

Very generally, the gas analyzer of the invention comprises a sample cell for containing a gas mixture to be analyzed. Infrared energy from a source is directed through the sample cell. A rotary filter wheel having at least one filter thereon for passing infrared energy at a wavelength band within the characteristic absorption band of a predetermined gas. The filter wheel is also provided with a dark level region substantially opaque to infrared energy. The filter wheel is supported and rotated to successively interpose the filter and the dark level region between the source and the sample cell in the path of the infrared energy directed by the source. Infrared energy passing through the sample cell is detected and an electrical signal is produced representative of the amplitude of the infrared energy. The electrical signal is processed to produce an output indicating the concentration of the predetermined gas in the sample cell. During the processing, the electrical signals produced by the detector with the filter positioned in the infrared energy path are compared with the signals produced when the dark level region is positioned in the infrared energy path. The dark level region has a substantially fully reflective surface oriented toward the sample cell when positioned in the infrared energy path. Accordingly, the infrared energy impinging on the dark level region is reflected substantially toward the detector.

Now referring to FIG. 1, a block diagram of the system of the present invention may be seen. An infrared source 11 of any suitable construction is located at one end of an infrared optical path 13 which terminates at the other end at a detector 15. In line in this optical path is a rotating filter wheel 17, which may be rotated by a motor 19 and belt drive 20 about an axis parallel to but offset from the optical path. Also in the optical path is a sample cell 21 into which the gas mixture to be analyzed is passed. For example, in the case of monitoring the intake and expiration of breath in a patient under anesthesia, the sample cell may be connected through a tube 23 to airway tubing attached to the patient.

In order to exhaust the sample gases from the sample cell 21, an exhaust tube 18 is provided which com-

municates through a pump 16. Periodic operation of the pump 16 can supply sample gas to the sample cell through the inlet tube 23.

A signal processor 24 is provided to process the output signals developed by the detector 15, which are synchronized with the position of the rotating filter wheel 17 to provide a plurality of measurements as described below. The rotating filter wheel may, for example, be driven directly, or by an appropriate 3450 RPM non-synchronous motor through a suitable drive belt or gear arrangement, not shown, so as to rotate at a speed of approximately 6,000 RPM.

The rotating filter wheel itself is better illustrated in FIG. 2, which schematically illustrates the face of the rotating filter wheel of the preferred embodiment. The rotating filter wheel is shown separated into six segments of sixty degrees each, with four of the six segments containing filters 25 through 29 and with the sixth angular segment being occupied by a solid portion of the wheel. Other combinations and numbers, however, could be used without departing from the scope of this invention. As will be subsequently shown, the filters 25 through 29 are each selected to pass narrow bands of infrared radiation, each having different band centers at predetermined wavelengths to provide four measuring signals and one reference signal. The sixth angular segment or region 31 of the wheel does not have a filter and is utilized to block the source radiation from the sample cell so that the detector signal may be used to indicate combined effects such as background radiation, detector null, electronics offset, etc. (i.e., background noise).

The sample cell 21 contains the gas mixture to be analyzed. The gas mixture includes a gas of interest being a selected one of a plurality of gases. Each of the gases has an absorption characteristic associated therewith, as below described. As the infrared energy passes through cell 21, the gas mixture absorbs a portion of such energy.

The detector 15 is responsive to the infrared energy passing through the cell 21. As each pulse of energy is passed by a filter in the filter wheel 17, a signal pulse is developed by the detector. Each pulse has an amplitude determined by the radiant energy passing through the cell 21 at the particular wavelength of the filter then interposed in the energy path. The pulse is applied to the signal processor 24.

Referring now to FIG. 3, there is shown, as an example only, an absorption ( $\alpha$ ) versus wavelength ( $\lambda$ ) representation illustrating a possible absorption characteristic for four gases A, B, C, and D, respectively. Each of gases A, B, C, and D has a characteristic absorption wavelength  $\lambda_a$ ,  $\lambda_b$ ,  $\lambda_c$ ,  $\lambda_d$ , respectively. The absorption of infrared energy passing through the sample cell is at the characteristic absorption wavelength  $\lambda_a$ - $\lambda_d$  (determined by the filters) of the respective one of gases A-D. The characteristic absorption being all wavelengths at which a gas absorbs infrared energy. One preselected wavelength  $\lambda_r$  (the reference filter) is chosen to be out-

side all of the absorption characteristics of gases A-D as shown in FIG. 3.

The gas analyzer of the present invention is particularly useful for analyzing the expired breath of a patient under anesthesia. Typical conditions will include carbon dioxide, water vapor, nitrous oxide, oxygen, and one or more of the previously mentioned anesthetic agent gases, such agents having a concentration in the expired breath of one to five percent or less typically. Each of these anesthetic agents absorbs infrared energy at a wavelength of about 3.3 microns.

The basic theory of operation of the system is as follows: The detector signal measured when the reference filter (wavelength  $\lambda_r$ ) is aligned in the optical path provides a measure of the basic sensitivity of the system to infrared radiation in general. That is, it provides a measure of the strength of the radiation of the infrared source, the attenuation of the radiation by (non-spectral) contamination and the like on the infrared transparent windows in the sample cell, and further provides a measure of the effectiveness of the collector and the sensitivity, of the detector as well as the gain of the processing electronics. Each of the other filters ( $\lambda_a - \lambda_d$ ) provide radiation which ideally can only be absorbed, if at all, by the presence of the specific gas (A-D) to be detected having an absorption characteristic corresponding to that filter. Of course, contamination on the windows, variations in the source radiation, detector characteristics, etc. will also vary the signal received, which sensitivity may be minimized by the use of the reference signal which is similarly affected.

In practice, for an evacuated sample cell, or in the alternative for a sample cell containing gases other than the gases to be detected, the detector signal versus rotating filter wheel angular position will be different. This is because of such effects as different optical characteristics of the filters, and source radiation and detector wavelength sensitivities. The four signals received will be of different amplitudes.

Difference in signal amplitude could be equalized optically, by controlling the aperture of each reference filter, or electronically by sampling the smaller signals for a longer time with a circuit sensitive to the time amplitude characteristics rather than mere amplitude or amplitude-fixed time product characteristic of the sensing. This is difficult, however, because such mechanical changes involve costly mechanical complexities and time consuming adjustment, and the fixed sample time circuits are by far the easiest to fabricate and use.

Another method of equalizing the signals would be to add an appropriate bias voltage to each of the signals to bring all of the signals up to predetermined level. This, however, would still result in a system which was sensitive to optical characteristic changes, since if the optical windows collected contamination so as to drop all signal strengths by twenty percent, the bias voltage would not drop accordingly, and the four signals would no longer be equal when the sample cell was free of the

gas to be detected. This would result in various output signals in a condition when no output signals should be present.

In the preferred embodiment, the detector signals for each of the five filters are measured for a predetermined angle of the filter wheel, utilizing a system having a different gain for each of the sensed signals predetermined to equalize the signals when none of the gases to be measured are present in the sample cell. Thus, variations in intensity of the radiation in the optical system caused by contamination on the sample cell windows, etc. will generally vary all signals in proportion so that the four gas signals and the reference signal will track each other with a high degree of accuracy.

In furtherance of the foregoing objective, it should be noted that there is a certain amount of background radiation present in any such system. This is radiation which will be incident upon the detector even when the infrared radiation source is off, or blocked from radiating into the sample cell by the solid portion of the rotating filter assembly. Other signals are also present which are functionally equivalent to the background radiation, such as possible null output of the detector, input offsets in the electronics, etc. These signals typically do not vary with variations in source intensity, window transmissibility, etc., and accordingly should be removed from all signals before the gain adjustment is made to equalize the outputs.

In some cases the wavelength of the reference filter will not be entirely outside the absorption band of all gases present in the sample cell. In these instances, some gain compensation may be needed which can be calculated and compensated for in the signal processor more particularly described below.

Returning now to FIG. 1, the signal processor 24 includes a preamplifier 33 connected to the output of the detector. A feedback loop extends from the output of the preamplifier 33 through a speed control circuit 35 to the motor 19 to stabilize the motor speed. The output of the detector 33 is also applied to a pulse normalization circuit 37 the output of which, in turn, is applied to a span stage circuit 39.

The pulse normalization circuit 37 operates to adjust the amplitude of the pulses output by the preamplifier 33 from the detector 15 to a standard or predetermined amplitude in the absence of a gas in the sample cell which absorbs at the particular wavelength of that pulse. The span stage 39, on the other hand, adjusts the gain of each pulse in accordance with the absorption characteristics of the gas corresponding to that particular wavelength. The gain of each pulse channel is selected so that a full pulse in the absence of any gas absorbing at that particular wavelength will be at a standard output voltage. Circuits for achieving pulse normalizations and span stage adjustment are well known in the art and will not be described with greater particularity herein. Any suitable pulse normalization circuit or span stage adjustment circuit may be utilized within the scope

of the present invention.

Operation of the pulse normalization circuit 37 and the span stage adjustment circuit 39 are controlled by a controller 41. The controller 41 may be any suitable microprocessor based controller and preferably contains memory for storing such information as filter parameters, gas absorption characteristics, etc. The particular program upon which the microprocessor operates is also preferably stored internally in a suitable ROM.

The output of the controller 41 is applied to a suitable display 43. The display 43 may comprise dials, digital displays or other appropriate indications of the concentrations of the gases of interest in the sample cell. The microprocessor controller 41 may also be controlled or its programs otherwise modified by means of an external operator keyboard, not shown.

Various operating conditions sensed by appropriate sensing devices, only some of which are illustrated, are applied to the controller 41 by a signal multiplexer and analog-to-digital converter 45. For example, the ambient temperature may be sensed by an ambient temperature sensor 47, which provides an analog output to the circuitry 45 which is then appropriately converted to corresponding digital information. Similarly, oxygen present at the exhaust tube 18 of the sample cell 21 may be sensed by an oxygen sensor 49 which applies an analog output to the circuitry 45. After multiplexing, the signals representing oxygen concentration and ambient temperature are then applied to an analog-to-digital converter and provided to the controller 41 for further processing.

A valve 51 is provided in the inlet tube 23. The valve 51 operates to close off the connection to the patient airway and to interconnect an ambient air intake and scrubber 53 to the inlet tube 23. When this is done, operation of the pump 16 purges the sample cell of all gases therein and replaces those gases with ambient air which has been scrubbed of carbon dioxide. When this is done, the controller can then adjust the pulse normalization stage 37 to recalibrate the normalization adjustments.

In operation of the device, output pulses from the detector 15 are amplified in the preamplifier 33 and are then adjusted in the pulse normalization circuit 37. The pulse normalization circuit adjusts the amplitude of the pulses in accordance with variations in the amplitude of the reference filter pulses, thereby eliminating drift caused by window contamination, etc.

In the span stage 39, the signal is once more adjusted to scale the pulses in accordance with the different absorption characteristics of the gases being measured. For example, the amplitude of the absorption caused by carbon dioxide may be many times higher than that caused by typical anesthetic agent gases. The span stage 39 permits these variations to be properly scaled.

As previously mentioned, various error causing factors can sometimes be eliminated by relatively expen-

sive features in gas analyzers. One such error causing factor is that the dark level sensed by the detector during the time that the region 31 is positioned in the optical path may vary. Variations in dark level are caused by background infrared radiation from a variety of sources and is of course present continuously in the system. It has been discovered that variations in the background level can occur depending on whether a filter is in the infrared energy path or whether the infrared energy path is blocked. This is because typical prior art devices block the infrared radiation by the interposition of an opaque portion of the filter wheel. Typically, the surface of the filter wheel absorbs or emits infrared radiation but does not reflect it. On the other hand, typical filter materials will, in addition to acting as windows to infrared radiation, also cause some reflection of such radiation. The difference between the absorption emission phenomenon and the reflection phenomena can result in a different background depending upon whether a filter is in the infrared path or whether the infrared path is blocked. This can result in a change in the pulse height which is spurious (i.e., which is not caused by a change in the measured gas at the pulse wavelength) because any gas other than the measured gas can produce different absorptions of the different backgrounds and so produce apparent changes in the transmitted pulse that are large compared with the absorption of the characteristic radiation by the gas being measured.

Although this problem could be eliminated by placing the filter wheel at the side of the sample cell adjacent the detector, such repositioning introduces other undesirable problems. In accordance with the invention, the variation in dark level problem described above is eliminated by making the opaque section of the filter wheel, indicated at 31 in FIGURE 2, reflective to infrared radiation. Any suitable reflective material may be utilized. By employing such material, variations in the background in the presence of the opaque region of the filter wheel in the radiation path versus filters interposed in the radiation path is eliminated.

As a further improvement from the above feature, the reflective surface of the opaque region 31 is positioned in the same plane as the reflective surface of the filters 25 through 29. By doing this, the average angle of the rays of light reflected from the opaque region is the same as that for the filters. This problem can be particularly acute where so called light pipe optics are utilized in the sample cell in order to maximize the path of light traveling through the cell. In other words, where the light rays are permitted to bounce off of the walls of the cell, rather being focused or collimated to pass cleanly through it, the path is lengthened for better response. However, because of the variation in light angles due to reflection from the walls of the sample cell and from the filters and opaque region on the filter wheel, the importance of having the reflective plane on the filter wheel uniform is significantly increased.

Problems in accuracy in gas analyzers of the type

to which the present invention relates are also introduced due to the presence of water vapor in the sample cell. This is particularly acute when the gases of interest include gases which have only a very low absorption, which is typical of halothane. Water vapor will have an absorption characteristic which interferes with some gases but not of others.

In accordance with the invention, a filter is utilized in the filter wheel 17 as a reference filter which will transmit two wavelengths. The two wavelengths passed by the filter are selected so that one wavelength is completely out of the absorption zone of water vapor and so that the other wavelength is completely in the absorption zone of water vapor. Both wavelengths are selected to be out of the absorption regions of any other gases expected to be present in the sample cell. By selecting the appropriate wavelengths, and by adjusting the amplitude of the infrared energy passed through the filter at those wavelengths, the variation in absorption of the other wavelengths of interest due to the presence of water vapor may be tracked perfectly by the dual wavelength reference filter. Such dual wavelength reference filters are available from Barr Associates, Massachusetts, U.S.A. By utilizing a single dual wavelength filter as above described, or a combination of two or more filters in series, optically, it is possible to compensate for the presence of water vapor without adding extra channels with consequent greater expense in the filter wheel and in the signal processing circuitry.

As previously mentioned, the use of so called light-pipe optics in the sample cell produces longer path lengths for the radiation and is therefore preferable where a fast response time (with lower sample cell size) is desired. It has been discovered, however, that typical materials employed for reflective surfaces for infrared radiation, such as polished aluminum, are highly adsorbent to water molecules. These water molecules are adsorbed (not condensed) on the walls of the sample tube, introducing error because of the wide band and variable absorption characteristics of water molecules. Materials which have a low adsorption for water molecules, such as stainless steel, are not highly reflective for infrared radiation and therefore are not satisfactory. It is possible to heat the sample cell to break the adsorption band of the water molecules on the walls, but such high temperatures (400 to 500 C) are required as to make this impractical.

In accordance with the invention, materials have been found which are sufficiently reflective to infrared radiation as to be capable of being employed in the sample cell, but which are sufficiently low in adsorption affinity for water molecules as to prevent the above described problem. Such materials include silicon oxide, magnesium fluoride and gold.

Another error factor which may be present in a gas analyzer results from the presence of ambient air in the radiation path in the spaces between the various elements of the gas analyzer. Since the ambient air present

may be different in certain gas concentrations from that present in the sample cell, and since ambient air can change with time after calibration of the instrument, error can result. Such error could be eliminated by filling the ambient air spaces or evacuating those spaces, but such expedients introduce significant expense.

A sealed gas cell is placed in the optical path filled with a fixed amount of carbon dioxide. The amount of carbon dioxide is selected to absorb sixty to seventy percent of the infrared radiation in the region of the carbon monoxide characteristic absorption wavelength band. At lower radiation intensity levels, the behavior of carbon dioxide more closely approximates the behavior of the other gases present in the sample cell and which are of interest. This reduces the overall sensitivity of the instrument to the presence of ambient air in the infrared energy path.

As previously mentioned, the gas analyzer of the invention may contain an automatic zeroing function. As a further feature of the present invention, this automatic zeroing is triggered upon the occurrence of three sensed conditions. The first of these conditions is time. The controller 41 is provided with a suitable internal clock, not shown, to produce an automatic zeroing instruction a predetermined time after warmup of the device. Such a predetermined time may, for example, be thirty minutes and is for the purpose of recalibrating the device once the various parts of the device have warmed up to their typical operating conditions. After warmup, the temperature levels of various parts can be significantly different than those existing immediately after a cold start.

In addition, the controller 41 is set to initiate automatic zeroing upon a predetermined change in ambient temperature. A change in ambient temperature can have a significant effect on the relative temperatures of the various parts and therefore on the accuracy of the device. An initiation of automatic zeroing upon sensing a change in ambient temperature of about five to ten degrees is typically preferred.

Finally, automatic zeroing is initiated by the controller 41 upon the sensing of a predetermined change in the amplitude of the pulse in the reference filter. A preferred level is of the order of 0.2 percent change. Such a rezeroing will recalibrate the device where significant changes have occurred in background conditions.

All of the foregoing features contribute, collectively, to a significant improvement in the stability and accuracy of the gas analyzer of the invention at a relatively modest cost as compared with what is taught by the prior art. This is because such expedients permit the use of less stable but cheaper parts in critical areas in the gas analyzer.

It may be seen, therefore, that the invention provides an improved gas analyzer which is particularly suited to the monitoring of anesthetic agents and associated gases. The analyzer of the invention has a fast response time along with a high accuracy and stability

and yet may be constructed at a reasonable price. Various modifications of the invention will become apparent to those skilled in the art from the foregoing description and accompanying drawings. Such modifications are intended to fall within the appended claims.

#### Claims

1. A gas analyzer comprising, a sample cell (21) for containing a gas mixture to be analyzed, source means (11) for producing and directing infrared energy through said sample cell (21), a rotary filter wheel (17) having at least one filter (25) thereon for passing infrared energy limited to a first wavelength band within the characteristic absorption band of a predetermined gas, said filter wheel further having a dark level region (31) substantially opaque to infrared energy, drive means for supporting and rotating said filter wheel to successively interpose said filter (25) and said dark level region (31) between said source means (11) and said sample cell (21) in the path (13) of the infrared energy directed by said source means (11), detector means (15) for detecting infrared energy having passed through said sample cell and producing an electrical signal representative thereof, signal processing means (24) connected to said detector means (15) for producing an output indicating the concentration of the predetermined gas in the sample cell (21) by comparing the electrical signals produced by said detector means (15) with said filter (25) positioned in the infrared energy path and with said dark level region (31) positioned in the infrared energy path (13), characterised in that said filter wheel (17) includes a second filter (26, 27, 28, or 29) for passing infrared energy limited to second and third wavelength bands, one of which is within a region of infrared absorption by water vapor and the other of which is not, both of said second and third wavelength bands of said second filter being outside the characteristic wavelength absorption regions of other gases present in the sample cell, the amplitude of infrared energy passed by said second filter at each of said second and third infrared wavelength bands being selected to trace the variation in absorption of infrared energy at said first wavelength band of said first filter (25) due to the presence of water vapor in said sample cell (21).
2. A gas analyzer according to Claim 1 wherein said dark level region (31) has a substantially fully reflective surface oriented toward said sample cell (21) when positioned in the infrared energy path such that infrared energy impinging thereon is reflected, and wherein said reflective surface of said dark level region (31) is positioned in substantially the same plane of rotation as the side of said filter facing said

sample cell.

3. A gas analyzer according to Claim 2 wherein the interior surfaces of said sample cell (21) are comprised substantially of a material having a low affinity for bonding with water molecules.
4. A gas analyzer according to Claim 3 wherein said material is selected from the group consisting of silicon oxide, magnesium fluoride and gold.
5. A gas analyzer according to Claim 1 including means for sensing the ambient temperature and for activating an automatic zeroing means upon a change in ambient temperature of said source means (11) by a predetermined amount.
6. A gas analyzer according to Claim 1 including a reference filter in said filter wheel (7), said signal processing means (24) including means for comparing the level of infrared energy passing through said sample cell (21) when said first filter (25) is interposed in the path of infrared energy and when said reference filter is interposed in the path of the infrared energy, means for monitoring the amplitude of the signal detected by said detector means (15) with said reference filter interposed in the path of infrared energy and for activating said automatic zeroing means upon a change in the level of said signal of a predetermined amount.

#### Patentansprüche

1. Gasanalysator mit einer Probenzelle (21) zur Aufnahme einer zu analysierenden Gasmischung, einer Quelle (11) zum Erzeugen und Richten von Infrarotenergie durch die Probenzelle (21), einem drehbaren Filterrad (17) mit mindestens einem Filter (25) zum Durchlassen von Infrarotenergie begrenzt auf ein erstes Wellenlängenband innerhalb des charakteristischen Absorptionsbandes eines vorgegebenen Gases, wobei das Filterrad ferner einen für Infrarotenergie im wesentlichen undurchlässigen Dunkelpegelbereich (31) aufweist, Antriebsmitteln zum Tragen und Rotieren des Filterrades, um nacheinander das Filter (25) und den Dunkelpegelbereich (31) zwischen der Quelle (11) und der Probenzelle (21) im Weg (13) der von der Quelle (11) gerichteten Infrarotenergie anzuordnen, einem Detektor (15) zum Detektieren von durch die Probenzelle durchgegangener Infrarotenergie und zum Erzeugen eines für diese repräsentativen elektrischen Signals, mit dem Detektor (15) verbundenen Signalverarbeitungsmitteln (24) zum Erzeugen eines Ausgangssignals, das die Konzentration des vorgegebenen Gases in der Probenzelle (21) anzeigt, durch Vergleich der elektrischen Signale, die

von dem Detektor (15) erzeugt werden, wenn das Filter (25) bzw. der Dunkelpegelbereich (31) in dem Weg (13) der Infrarotenergie angeordnet ist, dadurch gekennzeichnet, daß das Filterrad (17) einen zweiten Filter (26, 27, 28 oder 29) enthält zum Durchlassen von Infrarotenergie in den Grenzen eines zweiten und dritten Wellenlängenbandes, von denen das eine im Bereich der Infrarotabsorption in Wasserdampf liegt und das andere nicht, wobei das zweite und dritte Wellenlängenband des zweiten Filters außerhalb der charakteristischen Wellenlängenabsorptionsbereiche von anderen in der Probenzelle vorhandenen Gasen sind, wobei die Amplitude der von dem zweiten Filter bei dem zweiten und dritten Wellenlängenband durchgelassenen Infrarotenergie so gewählt ist, daß die Variation der Absorption von Infrarotenergie in dem ersten Wellenlängenband des ersten Filters (25) aufgrund des Vorhandenseins von Wasserdampf in der Probenzelle (21) erfaßt wird.

2. Gasanalysator nach Anspruch 1, bei dem der Dunkelpegelbereich (21) eine im wesentlichen vollständig reflektierende Oberfläche hat, die der Probenzelle (21) zugewendet ist, wenn sie in dem Weg der Infrarotenergie angeordnet ist, so daß darauf auftreffende Infrarotenergie reflektiert wird, und wobei die reflektierende Oberfläche des Dunkelpegelbereichs (21) im wesentlichen in der gleichen Rotationsebene angeordnet ist, wie die der Probenzelle zugewandte Seite des Filters.
3. Gasanalysator nach Anspruch 2, bei dem die inneren Oberflächen der Probenzelle (21) im wesentlichen aus einem Material bestehen, das eine niedrige Affinität für die Bindung mit Wassermolekülen hat.
4. Gasanalysator nach Anspruch 3, bei dem das Material ausgewählt ist aus Siliziumoxid, Magnesiumfluorid und Gold.
5. Gasanalysator nach Anspruch 1, mit Mitteln zum Erfassen der Umgebungstemperatur und zum Aktivieren einer automatischen Nullstelleinrichtung bei Änderung der Umgebungstemperatur der Quelle (11) um einen vorgegebenen Betrag.
6. Gasanalysator nach Anspruch 1, mit einem Referenzfilter in dem Filterrad (7), wobei die Signalverarbeitungsmittel (24) Mittel zum Vergleichen des Pegels der Infrarotenergie, die durch die Probenzelle (21) durchtritt, wenn das erste Filter (25) in dem Weg der Infrarotenergie angeordnet ist, und wenn das Referenzfilter in dem Weg der Infrarotenergie angeordnet ist, Mittel zum Überwachen der Amplitude des von dem Detektor (15) bei im

Weg der Infrarotenergie angeordneten Referenzfilter detektierten Signals, und zum Aktivieren der automatischen Nullstelleinrichtung bei einer Änderung des Pegels des Signals um einen vorgegebenen Betrag, aufweist.

## Revendications

1. Analyseur de gaz, comprenant une cellule d'échantillonnage (21) destinée à contenir un mélange gazeux à analyser, un dispositif (11) à source destiné à produire et diriger de l'énergie infrarouge à travers la cellule d'échantillonnage (21), une roue rotative (17) de filtre possédant au moins un filtre (25) destiné au passage de l'énergie infrarouge limitée à une première bande de longueurs d'onde dans la bande caractéristique d'absorption d'un gaz prédéterminé, la roue de filtre possédant en outre une région (31) de niveau d'obscurité qui est pratiquement opaque à l'énergie infrarouge, un dispositif d'entraînement destiné à supporter et faire tourner la roue de filtre afin que le filtre (25) et la région (31) de niveau d'obscurité soient successivement interposés entre le dispositif à source (11) et la cellule d'échantillonnage (21) sur le trajet (13) de l'énergie infrarouge dirigée par le dispositif à source (11), un dispositif détecteur (15) destiné à détecter l'énergie infrarouge ayant traversé la cellule d'échantillonnage et à produire un signal électrique représentatif de cette énergie, et un dispositif (24) de traitement de signaux connecté au dispositif détecteur (15) et destiné à produire un signal de sortie représentatif de la concentration du gaz prédéterminé dans la cellule d'échantillonnage (21) par comparaison des signaux électriques produits par le dispositif détecteur (15) lorsque le filtre (25) est placé sur le trajet de l'énergie infrarouge et lorsque la région (31) de niveau d'obscurité est placée sur le trajet (13) de l'énergie infrarouge, caractérisé en ce que la roue de filtre (17) possède un second filtre (26, 27, 28 ou 29) destiné à transmettre l'énergie infrarouge limitée à une seconde et une troisième bande de longueurs d'onde dont l'une se trouve dans une région d'absorption infrarouge de la vapeur d'eau et l'autre non, la seconde et la troisième bande de longueurs d'onde du second filtre se trouvant en dehors des régions d'absorption caractéristique en longueurs d'onde des autres gaz présents dans la cellule d'échantillonnage, l'intensité de l'énergie infrarouge transmise par le second filtre, dans chacune des seconde et troisième bandes de longueurs d'onde infrarouge, étant sélectionnée afin qu'elle suive la variation d'absorption d'énergie infrarouge dans la première bande de longueurs d'onde du premier filtre (25) à cause de la présence de la vapeur d'eau dans la cellule d'échantillonnage (21).



2. Analyseur de gaz selon la revendication 1, dans lequel la région (31) de niveau d'obscurité a une surface pratiquement totalement réfléchissante orientée vers la cellule d'échantillonnage (21) lorsqu'elle est placée sur le trajet de l'énergie infrarouge afin que l'énergie infrarouge qui parvient sur elle soit réfléchie, et dans lequel la surface réfléchissante de la région (31) de niveau d'obscurité est placée pratiquement dans le même plan de rotation que le côté du filtre tourné vers la cellule d'échantillonnage. 5 10
3. Analyseur de gaz selon la revendication 2, dans lequel les surfaces internes de la cellule d'échantillonnage (21) sont formées pratiquement d'un matériau présentant une faible affinité pour la liaison aux molécules d'eau. 15
4. Analyseur de gaz selon la revendication 3, dans lequel le matériau est choisi dans le groupe qui comprend l'oxyde de silicium, le fluorure de magnésium et l'or. 20
5. Analyseur de gaz selon la revendication 1, comprenant un dispositif de détection de la température ambiante et d'activation d'un dispositif de mise à zéro automatique lors d'un changement de la température ambiante du dispositif à source (11) d'une amplitude prédéterminée. 25
6. Analyseur de gaz selon la revendication 1, comprenant un filtre de référence placé dans la roue de filtre (7), le dispositif (24) de traitement de signaux comprenant un dispositif destiné à comparer les niveaux de l'énergie infrarouge traversant la cellule d'échantillonnage (21) lorsque le premier filtre (25) est placé sur le trajet de l'énergie infrarouge et lorsque le filtre de référence est placé sur le trajet de l'énergie infrarouge, et un dispositif de contrôle de l'amplitude du signal détecté par le dispositif détecteur (15) avec interposition du filtre de référence sur le trajet de l'énergie infrarouge étant destiné à activer le dispositif de mise à zéro automatique lors d'un changement du niveau du signal d'une quantité prédéterminée. 30 35 40 45

50

55

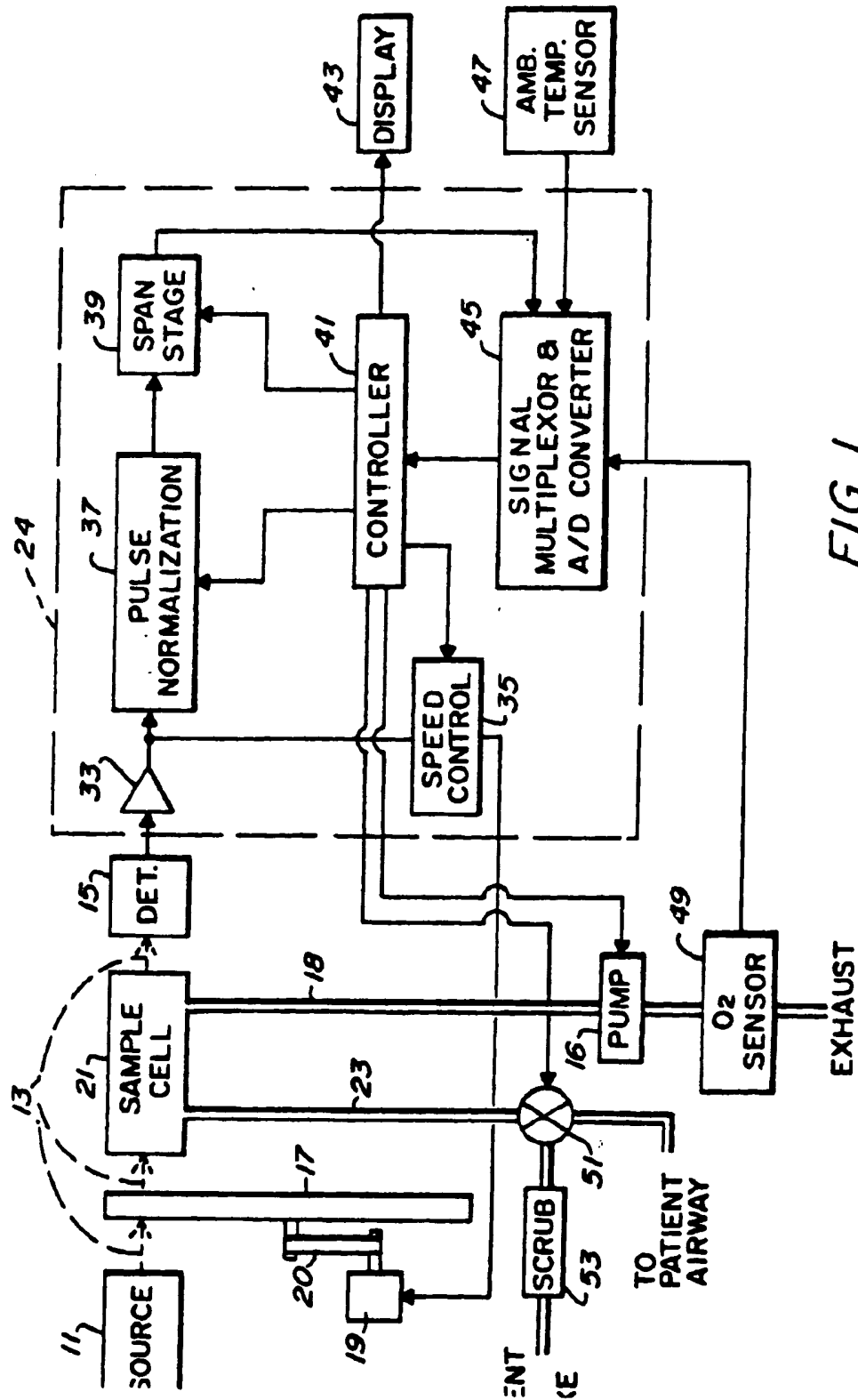


FIG. 2

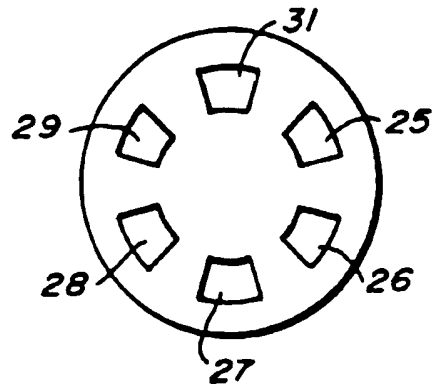


FIG. 3

